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Empirical Investment Equations in Developing Countries

Martin Rama

Investment decisions in developing countries face some additional constraints than in industrial countries. Analysts must consider such additional factors as financial repression, shortage of foreign exchange, lack of infrastructure, and significant economic instability. Rama suggests a method for improving empirical investment equations in developing countries.

This paper — a product of the Macroeconomic Adjustment and Growth Division, Country Economics Department — is part of a larger effort in PRE to understand the behavior of investment in adjustment programs. Copies are available free from the World Bank, 1818 H Street NW, Washington DC 20433. Please contact Emily Khine, room N11-067, extension 39361 (48 pages, including charts).

Since the debt crisis, there has been increasing interest in the determinants of investment in developing countries. There is plentiful literature on the topic for industrial economies but existing studies on developing countries are scattered and few.

Rama examined those studies with an eye to answering two questions: Are the variables that influence investment decisions the same in developing as in industrial countries, or should other factors be considered because the macroeconomic setting is different? And what can be learned from the applied research that has been done on the subject?

After revisiting the theoretical debate, Rama presents an integrative analytical framework, including different empirical equations, that depend on the assumptions made about the economies' key features (such as market structure and credit rationing). He classifies 25 empirical studies on investments in developing countries, classifying them according to their chosen specification and comparing their estimates.

Rama concludes that investment decisions in developing countries are not necessarily based on the same variables as in industrial countries. Analysts must consider such additional factors as financial repression, shortage of foreign exchange, lack of infrastructure, and significant economic instability.

In general, the available empirical studies support these arguments somewhat, so their

careful introduction into the theoretical models from which investment equations are drawn deserves further research. This is particularly true for the intertemporal aspects of analysis, restrained in Rama's analysis to a simple two-period framework.

With a few exceptions the available empirical studies are not satisfactory, Rama finds. The endogenous variable is seldom scaled, so it probably gathers a time trend. And some key exogenous variables — such as the user cost of capital, the upper bounds on credit, and the availability of foreign exchange — are measured in misleading ways. The measurement issue deserves more research.

Rama stresses the importance of the aggregation procedure when there is significant economic instability. Sudden and dramatic policy changes modify the relevant investment rule. By raising or reducing the share of firms that face credit or foreign exchange rationing, these changes prevent use of a representative-firm approach.

Finally, Rama proposes a method for dealing with the effects on private investment of the economic instability typical in most developing countries.

Applied research would help decide whether the suggested procedure improves the econometric performance of empirical investment equations in developing countries.

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Empirical Investment Equations in LDCs*

by
Martin Rama **

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1. INTRODUCTION

Since the debt crisis, there has been an increasing interest in the determinants of private investment in less developed countries (LDCs). For industrialized countries, there is plentiful literature on this topic, referring to the available theoretical models (see the surveys by Nickell, 1978, or Artus and Muet, 1986), as well as to the empirical results obtained when using different specifications (see Abel 1980, or Artus and Muet, 1984, among others). But with relation to LDCs, the existing studies are still partial and scattered.

Two main questions should be addressed concerning private investment decisions in LDCs. The first one, theoretical, concerns the variables on which the decisions depend: are they the same as in industrialized countries, or should we consider specific factors, arising from a different macroeconomic setting? The second question has an empirical content, related to the available estimates: what can we learn from the applied research that has already been done on the determinants of private investment in LDCs?

This paper seeks to provide a preliminary answer to both questions. In the next section, the theoretical debate on the specific factors that should be taken into account in LDCs is revisited. Section 3 introduces the main outcomes of such a debate into a single analytical framework, which gives rise to different empirical equations depending on the assumptions made concerning some key features of the economy (market structures, credit rationing, etc.). In the following section, twenty-five empirical studies on investment in LDCs are classified according to their chosen specification, and their estimates are compared. Finally, section 5 gathers a methodological proposal for further research, particularly as regards the impact that the economic instability characterizing most LDCs has on private investment.

2. SOME SPECIFIC ISSUES

The literature on investment decisions in industrialized countries stands basically on two arguments. The first one is related to changes in aggregate demand and gives rise to the "income accelerator". The second one concerns relative prices of capital and labor (or more generally, variable inputs), and therefore profitability. These arguments are both considered by the literature on private investment in LDCs. However, four other arguments are usually added, which arise from specific features of these countries.

Financial repression

Since the works by Mc Kinnon (1973) and Shaw (1973), it has been widely accepted that a significant share of LDCs' firms face credit rationing. This kind of quantity constraint may be relevant in industrialized countries also, as a result of the different information available to creditors and debtors. However, in addition to the information problem, LDCs are often characterized by administered interest rates which are set up at "low" levels, and by direct credit allocation for the benefit of some firms. The impact of such a policy choice on private investment is amplified by the weakness of capital markets in LDCs, which restrains the access of the firms to additional equity capital.

According to this approach, ceilings are more relevant than spreads for credit allocation in LDCs. This means that the individual firm does not face unlimited credit supplies at a given interest rate, as would be the case in a Modigliani-Miller

world. Moreover, unlimited credit supplies with interest rates increasing in line with the firm's debt-to-equity ratio do not seem likely either. Instead, the firm would have access (at most) to a given credit ceiling, but the interest rate would always be the administered one, whatever the amount borrowed.¹

At the macroeconomic level, this possible constraint on the investment level had been already considered by the two-gap model, developed in the '60s by Mc Kinnon (1964) and Chenery and Strout (1966), among others. This model assumed that domestic savings, the world demand for exports, and foreign financing were given. The sum of domestic savings and foreign financing put an upper bound on total investment (thus giving rise to a saving gap), whereas the sum of exports and foreign financing set up the maximum imports level (leading to a foreign exchange gap). Since the first of these two gaps is related to interest rates which do not clear the market, its effects are quite similar to those arising from credit rationing.

Financial repression has an important consequence from the research viewpoint. Despite the existence of an investment function, in some periods the observed capital accumulation could be determined by the amount of saving forthcoming at the prevailing interest rate. Therefore, the microeconomic foundations of investment decisions should be analyzed by means of an equilibrium-with-rationing approach, like the one that characterizes fix-price models (see Malinvaud, 1977).²

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- 1/ However, if there was a spillover of the credit demand to curb markets, the average interest rate would indeed rise in line with the amount borrowed by the firm.
- 2/ Other disequilibria considered by these models do not seem relevant to explain private investment in LDCs. This is the case, particularly, with manpower shortage..

Foreign exchange shortage

Since most capital goods must be imported by LDCs, the kind of foreign exchange shortage considered by the two-gap model can be an additional constraint on private investment. This would be the case if balance-of-payment difficulties (associated, for instance, with the debt crisis) led to the use of direct exchange allocation or to the setting up of import quotas. Such policy devices would introduce an upper bound on machinery and equipment purchases which are usually made abroad, and cannot be easily replaced by domestic substitutes.³

The discussion on the determinants of private investment in LDCs would not be complete if such a possible constraint were not explicitly taken into account. From the point of view of empirical research, its consequences are similar to those of credit rationing. In both cases, the investment equation to be used must arise from an optimization problem explicitly including the possibility of quantity rationing.

Lack of infrastructure

It is usually accepted that private investment can fall as a result of a higher public investment when the latter rests on scarce financial resources. In industrialized countries, this crowding-out effect is induced by higher interest rates. In LDCs in which financial repression prevails, it can arise from a tight credit rationing at the prevailing administered interest rate. However, public investment could also impose a positive externality on private investment in countries characterized by

3/ However, notice that in many LDCs such devices aim at restraining sumptuary consumption purchases, rather than input and investment imports.

lack of infrastructure, or by weaknesses in the provision of public goods. In this case, public capital accumulation would be complementary to private investment.

This ambiguous relationship between public and private investment represents a challenge to applied research. On the one hand, empirical estimates should provide an answer on whether or not the lack of infrastructure is important enough to give rise to a significant externality. On the other hand, these estimates should help to decide whether the crowding-out effect dominates the positive externality or the opposite.

Economic instability

Some of the variables relevant for investment decisions experience larger fluctuations in LDCs than in industrialized countries. This is partly due to a different economic structure, particularly as regards sectoral diversification. For instance, there may be important variations of the real exchange rate in countries whose exports are concentrated in a few raw materials or agricultural products. Notwithstanding, a large share of the instability which characterizes most LDCs results from political and institutional factors. In fact, the larger changes in the real exchange rate often result from policy-induced over- or under-valuation of the domestic currency. The same holds for credit availability, aggregate demand, and other variables whose level depends on sudden (and sometimes dramatic) changes in economic policy.

If firm owners were risk averse, lower investment levels would result from such an instability, because of the larger variance in expected profits. The result would be similar if investment were irreversible (at least partly), thus giving rise to sunk costs whenever capacity utilization fell (Bertola, 1987;

Pindyck, 1988). But even if firm owners were risk neutral and capital goods could be resold, there would be important consequences for empirical research. Dramatic economic policy changes (such as the adoption of adjustment programs) put forward the Lucas critique. So, different specifications should be used for the investment function, depending on the prevailing macroeconomic conditions.

3. AN INTEGRATIVE FRAMEWORK

Three of the specific issues discussed above, namely: financial repression, foreign exchange shortage and lack of infrastructure, can be introduced in a rigorous manner into the investment equations usually considered for empirical research. This is done here by means of a single analytical model, from which different specifications can be drawn. As regards economic instability, which was the fourth issue, its consequences on the specification of empirical investment equations are discussed in section 5.

Objective function and constraints

Consider the investment decisions of a single representative firm which seeks to maximize the sum of its discounted dividends or, tantamount, the increase of its market value ΔV , over a finite horizon. This dynamic feature of the investment decision can be taken into account by considering just two periods: "present" (t) and "future" ($t+1$):

$$\Delta V = (p_t \cdot Q_t - w_t \cdot L_t) + [v_t \cdot KP_t - v_{t-1} \cdot (1 + r_{t-1}) \cdot KP_{t-1}]$$

$$\begin{aligned}
& - v_t \cdot KP_t \cdot (u_t + \frac{\Gamma}{2} \cdot u_t) \\
& + \frac{1}{1 + r_t} \cdot (p_{t+1} \cdot Q_{t+1} - w_{t+1} \cdot L_{t+1}) + \frac{v_{t+1} \cdot KP_{t+1}}{1 + r_t} - v_t \cdot KP_t
\end{aligned}$$

In this equation, Q stands for total output, KP for the capital stock and L for the employment level, whereas p , v and w represent the corresponding nominal prices and wages. Besides, r is the discount rate, which will be treated as given.⁴

The first term in the right-hand side of the equation represents current profits in period t . The second one measures capital gains or losses during the first period, which arise from changes in the market price of the firm's machinery and equipment. Since none of these two terms depend on the investment level, they are hereafter replaced by Z_t and treated as given. The third term is a convex function of the investment rate u_t , which is the ratio between gross investment IP_t and the already existing capital stock KP_t . The whole third term is equal to (larger than) IP_t when the parameter Γ is null (strictly positive).⁵ The fourth term stands for the discounted value of future current profits, whereas the last one corresponds to capital gains or losses in the second period.

The firm's optimization problem includes a set of technological and economic constraints. Among the former is the motion law of the capital stock, which depends on the investment level and the depreciation rate δ :

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- 4/ Steigum (1983) and Chirinko (1987) analyze the case in which the interest rate r (and therefore, investment decisions themselves) depends on the debt-to-equity ratio of the firm.
- 5/ Notice that the capital price v_t is the same in this term as in the previous one, thus reflecting the assumption that capital goods can be resold.

$$KP_{t+1} = \frac{KP_t + IP_t}{1 + \delta} = KP_t \cdot \frac{1 + u_t}{1 + \delta}, \quad 0 \leq \delta < 1 \quad (1)$$

The production function is the second technological constraint on investment decisions. We assume, for simplicity:

$$Q_{t+1} = f(KG_{t+1}, KP_{t+1}, L_{t+1}) = KG_{t+1}^{\tau} \cdot KP_{t+1}^{\alpha} \cdot L_{t+1}^{\beta} \quad (2)$$

$$\tau \geq 0, \quad 0 < \alpha < 1, \quad 0 < \beta < 1$$

In equation (2), KG represents the public sector's capital stock, and measures the development reached by the country's infrastructure. A larger KG imposes a positive externality on private production whenever $\tau > 0$. For $\tau = 0$, on the contrary, equation (2) is just a standard Cobb-Douglas production function. Note further that $\beta = 0$ corresponds to the fixed coefficients case, with private capital stock as the scarce production factor.⁶

Economic constraints arise from the structure of the markets in which the firm operates. Concerning the firm's output, a quite general specification is obtained by assuming the following demand curve:

$$Q_{t+1} = (Y_{t+1}/J) \cdot \left(\frac{P_{t+1}}{P_{t+1}} \right)^{-\sigma} \quad (3)$$

6/ A third technological constraint would be $IP_t \geq 0$. However, throughout the paper it will be assumed that determinants of investment are such as to avoid the corner solution $IP_t = 0$.

In equation (3), Y represents real aggregate demand, J is the number of firms in the whole economy, and P (uppercase) the general price index. Therefore, p/P is the relative price of the firm's output.⁷

Depending on the value of σ , different market structures are obtained. The firm operates in monopolistic competition when $\sigma > 1$, in which case p_{t+1} is one of its control variables. Besides, it operates in a perfectly competitive market when $\sigma \rightarrow +\infty$, whereas it faces a sales constraint like those considered by fix-price models when $\sigma = 0$. In these two cases, the price is given at the level $p_{t+1} = P_{t+1}$, so that it does not represent a control variable of the firm anymore.

Concerning the other markets, the discussion in section 2 points out that credit and foreign exchange shortages are likely in LDCs. If the firm is unable to borrow beyond a certain limit, investment expenditures are bounded by:

$$v_t \cdot K P_t \cdot \left(u_t + \frac{\Gamma}{2} u_t \right) \leq P_t \cdot F_t \quad (4)$$

where F represents the sum (measured in real terms) of internal financing, net credit and additional equity-capital available for the firm (P is the general price index defined above).

The second possible quantity constraint is related to the use of direct foreign exchange allocation as a device to reduce the purchases made abroad. Assuming that a given share ϕ of total investment must be imported, the rationing scheme implies:

$$\phi \cdot I P_t \leq \frac{x_t \cdot A_t}{v_t}, \quad 0 < \phi \leq 1 \quad (5)$$

7/ A micro-foundation for this kind of demand function is provided by Dixit and Stiglitz (1977).

with A_t representing the total amount of foreign currency available to the firm, and x_t being the corresponding exchange rate.⁸ If quantity restrictions were used instead of administered foreign exchange allocation, $x_t A_t / v_t$ would directly measure the allowed import quota.

Monopolistic competition

Assume that monopolistic competition prevails in the goods market ($\sigma > 1$) and that there are no investment costs ($\Gamma = 0$). By replacing equation (1) in ΔV , the firm's objective function can be rewritten as:

$$\Delta V = Z_t + \frac{1}{1 + r_t} \cdot (p_{t+1} \cdot Q_{t+1} - c_{t+1} \cdot K p_{t+1} - w_{t+1} \cdot L_{t+1})$$

with: $c_{t+1} \approx v_t \cdot (\delta + r_t - \frac{v_{t+1} - v_t}{v_t})$, since $\delta \cdot r_t \approx 0$

Here, c_{t+1} is the standard analytical expression for the user cost of capital, i.e. for the flow price for capital services. Indeed, the term δ is the depreciation charge per unit of capital, whereas $r_t = (v_{t+1} - v_t) / v_t$ can be seen as a real interest rate evaluated with respect to the market price of capital goods. The c_{t+1} variable allows to transform the intertemporal optimization problem into a traditional static one.

8/ Equation (5) is written as if the price of capital goods were the same whatever their origin (imported or domestically produced).

The firm maximizes V with respect to its future price p_{t+1} and its future capital stock KP_{t+1} . Taking into account equations (2) and (3), the objective function becomes:

$$V = Z_t + \frac{1}{1+r_t} \cdot [p_{t+1} \cdot (Y_{t+1}/J) \cdot P_{t+1}^\sigma - c_{t+1} \cdot KP_{t+1} \\ - w_{t+1} \cdot (Y_{t+1}/J) \cdot p_{t+1}^{1/\beta} \cdot P_{t+1}^{-\sigma/\beta} \cdot KG_{t+1} \cdot KP_{t+1}^{-\tau/\beta} \cdot P_{t+1}^{-\alpha/\beta}]$$

The first-order condition with respect to p_{t+1} gives rise to a standard mark-up equation on labor costs:

$$\frac{p_{t+1}}{P_{t+1}} = \left(\frac{\sigma}{\sigma-\theta} \right) \cdot (Y_{t+1}/J) \cdot KG_{t+1}^{(1-\beta)/\theta} \cdot KP_{t+1}^{-\tau/\theta} \cdot P_{t+1}^{-\alpha/\theta} \cdot \left(\frac{w_{t+1}}{P_{t+1}} \right)^{\beta/\theta}$$

with $\theta = \beta + (1-\beta)\sigma$. The mark-up ratio rises in line with aggregate demand, decreases with private capital stock and decreases also (for $\tau > 0$) with the country's infrastructure.

The firm's optimal capital stock is obtained by replacing this result in the first-order condition associated with KP_{t+1} :

$$KP_{t+1}^{(\alpha+\beta)+(1-\alpha-\beta)\sigma} = \left(\frac{\alpha}{\beta} \right) \cdot \left(\frac{\theta}{\sigma} \right) \cdot (Y_{t+1}/J) \cdot KG_{t+1}^{\tau(\sigma-1)} \cdot \left(\frac{c_{t+1}}{P_{t+1}} \right)^{-\theta} \cdot \left(\frac{w_{t+1}}{P_{t+1}} \right)^{-(\sigma-\theta)}$$

In order that KP_{t+1} correspond to the maximum ΔV , the second-order condition must also be fulfilled. Intuitively, for $\sigma > 1$ it is necessary to verify $\alpha+\beta < \sigma/(\sigma-1)$. Otherwise, the exponent of KP_{t+1} in the equation above would be negative, so that the optimal capital stock would increase with the user cost of capital, decrease with aggregate demand, etc..

The optimal investment rule under monopolistic competition is obtained by rewriting the equation above in growth rates, hereafter indicated by a hat. Provided that:

$$\hat{KP}_{t+1} \approx \frac{IP_t}{KP_t} - \delta$$

(see equation (1)) and replacing θ by its analytical expression:

$$\frac{IP_t}{KP_t} = \delta + \phi_{R1} \cdot (\hat{Y}_{t+1}/J) + \phi_{R2} \cdot \hat{KG}_{t+1} + \phi_{R3} \cdot \left(\frac{\hat{C}_{t+1}}{P_{t+1}} \right) + \phi_{R4} \cdot \left(\frac{\hat{W}_{t+1}}{P_{t+1}} \right) \quad (6)$$

with:

$$\phi_{R1} = \frac{1}{(\alpha+\beta)+(1-\alpha-\beta)\sigma} > 0, \quad \phi_{R2} = \frac{\tau(\sigma-1)}{(\alpha+\beta)+(1-\alpha-\beta)\sigma} \geq 0$$

$$\phi_{R3} = - \frac{\beta+(1-\beta)\sigma}{(\alpha+\beta)+(1-\alpha-\beta)\sigma} < 0, \quad \phi_{R4} = - \frac{\beta(\sigma-1)}{(\alpha+\beta)+(1-\alpha-\beta)\sigma} < 0$$

Equation (6) is the kind of analytical expression developed for industrialized countries by Blanchard (1988) or, in a more elaborate framework, by Sneessens (1987). Its main interest is to provide a micro-foundation for the arguments usually considered when dealing with data. Indeed, the second term in the right-hand side of equation (6) can be seen as an income accelerator. Concerning the last two terms, they capture the effects of changes in relative factor prices.

What is added by equation (6) is the effect of a larger infrastructure on private investment (second term). Thus, the equation captures one of the arguments of the literature on

investment in LDCs which was discussed above. Such an effect arises from the specification of the production function and is embodied in coefficient ϕ_{R2} , which is positive whenever $\tau > 0$.

Finally, notice that the structural parameters α , β , τ and σ can be drawn from the ϕ coefficients in equation (6):

$$\alpha = \frac{1 + \phi_{R3}}{\phi_{R1} + \phi_{R3} + \phi_{R4}}, \quad \beta = \frac{\phi_{R4}}{\phi_{R1} + \phi_{R3} + \phi_{R4}}$$

$$\tau = - \frac{\phi_{R2}}{\phi_{R1} + \phi_{R3} + \phi_{R4}}, \quad \sigma = - \frac{\phi_{R3} + \phi_{R4}}{\phi_{R1}}$$

Concerning δ , no additional calculations are required.

The "true" neoclassical case

From equation (6), it is straightforward to derive the optimal investment rule under perfect competition. In this case, the firm faces an infinitely elastic demand curve ($\sigma \rightarrow +\infty$) at a given price ($p_{t+1} = P_{t+1}$). By using limits, equation (6) yields:

$$\frac{IP_t}{KP_t} = \delta + \phi_{N2} \cdot \hat{KG}_{t+1} + \phi_{N3} \cdot \left(\frac{\hat{C}_{t+1}}{P_{t+1}} \right) + \phi_{N4} \cdot \left(\frac{\hat{W}_{t+1}}{P_{t+1}} \right) \quad (7)$$

with:

$$\phi_{N2} = \frac{\tau}{1 - \alpha - \beta} \geq 0, \quad \phi_{N3} = - \frac{1 - \beta}{1 - \alpha - \beta} < 0, \quad \phi_{N4} = - \frac{\beta}{1 - \alpha - \beta} < 0$$

The restriction required on the production function parameters in order to fulfill the second-order condition is now $\alpha + \beta < 1$.

These parameters verify:

$$\alpha = \frac{1 + \phi_{N3}}{\phi_{N3} + \phi_{N4}}, \quad \beta = \frac{\phi_{N4}}{\phi_{N3} + \phi_{N4}}, \quad \gamma = - \frac{\phi_{N2}}{\phi_{N3} + \phi_{N4}}$$

Investment rules like the one represented by equation (7) have been seldom used in industrialized countries (an exception is the paper by Schramm, 1972). One possible explanation is that the omission of an income accelerator effect leads to disappointing empirical results. But in addition, what has been usually identified as the "neoclassical" investment function is a specification quite different from equation (7).

Effective demand (the so-called "neoclassical model")

At the opposite of perfect competition, it could be assumed that the firm faces quantity rationing in the goods market. This is likely to occur when prices are set by the government, or when they result from prior contracts. In terms of equation (3), demand is fully inelastic with respect to relative prices ($\sigma = 0$) so that sales have to be taken as given at the level (Y_{t+1}/J) . Replacing $\sigma = 0$ in the ϕ coefficients of equation (6) yields the following investment rule:

$$\frac{IP_t}{KP_t} = \delta + \phi_{K1} \cdot \left(\frac{Y_{t+1}}{J} \right) + \phi_{K2} \cdot KG_{t+1} + \phi_{K3} \cdot \left(\frac{C_{t+1}}{W_{t+1}} \right) \quad (8)$$

with:

$$\phi_{K1} = \frac{1}{\alpha + \beta} > 0, \quad \phi_{K2} = -\frac{\tau}{\alpha + \beta} \leq 0, \quad \phi_{K0} = -\frac{\beta}{\alpha + \beta} < 0$$

and structural parameters α , β and τ given by:

$$\alpha = \frac{1 + \phi_{K0}}{\phi_{K1}}, \quad \beta = -\frac{\phi_{K0}}{\phi_{K1}}, \quad \tau = -\frac{\phi_{K2}}{\phi_{K1}}$$

In this case, no restrictions are required on the returns to scale $\alpha + \beta$.

According to equation (8), if the firm faces a sales constraint, its investment rate is a decreasing function of the growth of the country's infrastructure ($\phi_{K2} \leq 0$). This Keynesian feature is in sharp contrast with the results arising from the market structures analyzed above. Therefore, it can be used in order to check whether or not the sales constraint is binding (a significantly positive estimate for ϕ_{K2} would suggest that actual σ is not null).

Except for the role of the public sector's capital stock, equation (8) is quite similar to the Jorgenson's (1963) investment rule. The latter, which has been widely used for empirical research in industrialized countries, is known as the "neoclassical model". This is because, unlike the "naive" income accelerator, it takes relative factor prices into account. However, equation (8) is also close to the investment rules arising from fix-price models (see, particularly, the analysis developed by Grossman, 1972).

The implicit approach (Tobin's q)

Assume now that there are significant investment costs, so that $\Gamma > 0$. Since the expected user cost of capital cannot be calculated anymore, the optimal investment rule will not depend on c_{t+1} . Instead, consider the following Lagrangian:

$$\begin{aligned}
 = & Z_t + \frac{1}{1+r_t} \cdot (p_{t+1} \cdot Q_{t+1} - w_{t+1} \cdot L_{t+1}) - v_t \cdot KP_t \cdot \left(u_t + \frac{\Gamma}{2} \cdot u_t^2 \right) \\
 & + \frac{v_{t+1} \cdot KP_{t+1}}{1+r_t} - v_t \cdot KP_t + v_t^* \cdot \left(KP_t \cdot \frac{1+u_t}{1+\delta} - KP_{t+1} \right)
 \end{aligned}$$

with v_t^* being the multiplier associated with the motion law of the capital stock (equation (1)). This co-state variable measures the contribution of an additional capital unit to the firm's market value. The control variables are now u_t , KP_{t+1} and L_{t+1} , thus leading to the following first-order conditions:

$$1 + \Gamma \cdot u_t = \frac{v_t^*}{v_t \cdot (1 + \delta)}$$

$$v_t^* = \frac{1}{1+r_t} \cdot [p_{t+1} \cdot f'_{KP}(KG_{t+1}, KP_{t+1}, L_{t+1}) + v_{t+1}]$$

$$f'_L(KG_{t+1}, KP_{t+1}, L_{t+1}) = \frac{w_{t+1}}{p_{t+1}}$$

According to the second equation above, the co-state variable gathers the discounted effects of a larger capital stock on future current profits, but also on the resale price of the firm. Therefore, v_t^* must be seen as the shadow price of

additional capital. The right-hand side of the equation above, in turn, is nothing but the **marginal** value of the q variable defined by Tobin (1969), since it measures the ratio between the shadow price of additional capital v_{t+1} (here, adjusted for depreciation) and its market price v_t .

Replacing the second equation into the first one leads to the following investment rule:

$$1 + \Gamma \cdot u_t = q_t = \frac{p_{t+1} \cdot f_{KMP}(KG_{t+1}, KP_{t+1}, L_{t+1}) + v_{t+1}}{v_t \cdot (1 + \delta) \cdot (1 + r_t)} \quad (9)$$

The problem with equation (9) is that only **average** q is statistically observable. Indeed, the stock market value of the firm provides information on the shadow price of already existing capital goods, i.e. on the sum of total discounted profits plus the resale price of total capital. But it does not necessarily provide information on the shadow price of investments to be done. This can be seen by replacing the analytical expression of the demand curve (equation (3)) and the last first-order condition into the right-hand side of equation (9), which yields for marginal q :

$$q_t = \frac{1}{v_t \cdot (1 + \delta) \cdot (1 + r_t)} \cdot \left[\alpha \cdot \beta^{\frac{(\sigma - \theta)/\theta}{\sigma - \theta}} \cdot \frac{-[(\alpha + \beta) + (1 - \alpha - \beta)\sigma]/\theta}{\cdot KP_{t+1}} \cdot \left(\frac{1/\theta}{\cdot (Y_{t+1}/J)} \cdot \frac{\tau(\sigma - 1)/\theta}{\cdot KG_{t+1}} \cdot \frac{\sigma/\theta}{\cdot P_{t+1} \cdot W_{t+1}} \cdot \frac{-(\sigma - \theta)/\theta}{+ v_{t+1}} \right) \right]$$

Marginal q is equal to the statistically observable q only if the exponent of KP in the equation above is zero. This is what happens when $\alpha + \beta = \sigma/(\sigma - 1)$, i.e. when increasing returns to scale are exactly offset by the price decrease resulting from a larger output. Of course, this is very unlikely to happen.

However, the assumption $\alpha + \beta = \sigma / (\sigma - 1)$ has been widely used in literature, in the hypothesis of perfect competition in the goods market ($\sigma \rightarrow +\infty$). In this case, the required restriction on the production function parameters is $\alpha + \beta = 1$ (Hayashi, 1982).⁹

For a capital stock KP , average q can be written, by definition, as:

$$\bar{q}_t(KP) = \int_0^{KP} (1/KP) \cdot q_t(k) \cdot dk$$

with the line over q indicating average. Replacing above the analytical expression of marginal q_t yields:

$$\bar{q}_t = q_t + \frac{(\alpha + \beta) + (1 - \alpha - \beta) \cdot \sigma}{(\sigma - 1) \cdot (1 + \delta)} \cdot \frac{p_{t+1} \cdot Q_{t+1}}{v_t \cdot (1 + r_t) \cdot KP_{t+1}}$$

It is worth noting that this result does not hold when $\sigma = 0$, i.e. when the firm faces quantity rationing in the goods market. Indeed, for any given price $p_{t+1} = P_{t+1}$, there exists a capital stock KP_m such that the firm would not face a sales constraint anymore if KP were lower than KP_m . Hence, in order to discuss the case $\sigma = 0$, a more complicated relationship between average and marginal q must be considered, in which the relevant demand curve is different depending on whether KP is lower or higher than KP_m (Precious, 1985).

In equilibrium, all firms set the same price, since they all face the same optimization problem. Hence, $p_{t+1} = P_{t+1}$ and $Q_{t+1} = Y_{t+1}/J$. By replacing into the analytical expression of average q , equation (9) leads to the following investment rule:

9/ If $\sigma = 0$, on the contrary, it is straightforward to verify that marginal q is a decreasing function of KP (Blanchard and Sachs, 1982).

$$\frac{IP_t}{KP_t} = \phi_{T6} \cdot (\bar{q}_t - 1) + \phi_{T7} \cdot y_{t+1} \quad (10)$$

with:

$$y_{t+1} = \frac{P_{t+1} \cdot (Y_{t+1}/J)}{v_t \cdot (1+r_t) \cdot KP_{t+1}}, \quad \phi_{T6} = 1/\Gamma > 0, \quad \phi_{T7} = - \frac{(\alpha+\beta) + (1-\alpha-\beta) \cdot \sigma}{\Gamma \cdot (\sigma-1) \cdot (1+\delta)}$$

Coefficient ϕ_{T7} is positive when $\alpha+\beta > \sigma/(\sigma-1)$, i.e. when increasing returns to scale more than offset the decrease in prices resulting from a larger output. Unfortunately, Γ is the only structural parameter of the model that can be drawn from the ϕ coefficients in equation (10).

The investment rule represented by equation (10) is similar to the one discussed by Sciantarelli and Georgoutsos (1990). In both cases, the empirical equation bridges the gap between the statistically observable average q and the relevant marginal q by means of a variable or a set of variables related to the business cycle. Indeed, the ratio y_{t+1} can be seen as an indicator of the discounted average productivity of capital (in value terms). In the case of a fixed coefficients technology ($\beta = 0$), i^+ represents a proxy for capacity utilization (Licandro, 1990). So, the inclusion of y_{t+1} in the investment rule provides a rationale for a current practice in empirical Tobin's q studies for industrialized countries (see for instance: von Furstenberg, 1977; Malkiel, von Furstenberg and Watson, 1979; and Chan-Lee and Torres, 1987).

Credit rationing

When the firm faces credit rationing, the constraint represented by equation (4) is binding. This equation can be rewritten as a polynomial of degree two in u_t :

$$\frac{\Gamma}{2} u_t^2 + u_t - \frac{P_t \cdot F_t}{v_t \cdot K P_t} = 0$$

with the only positive root given by:

$$u_t = -\frac{1}{\Gamma} + \frac{1}{\Gamma} \left(1 + 2\Gamma \cdot \frac{P_t \cdot F_t}{v_t \cdot K P_t} \right)^{1/2}$$

Taking a second-order Taylor development around $F_t = 0$, the following investment rule is obtained:

$$\frac{I P_t}{K P_t} = \frac{P_t \cdot F_t}{v_t \cdot K P_t} + \phi_{FS} \cdot \left(\frac{P_t \cdot F_t}{v_t \cdot K P_t} \right)^2, \quad \phi_{FS} = -\Gamma \quad (11)$$

The second term in the right-hand side of equation (11) is approximately zero when investment costs are not large, but strictly negative otherwise. Notice that no restriction is required on the parameters of the model. But as in the implicit approach, the latter cannot be directly drawn from the coefficients of the reduced form.

Equations like (11) are used in industrialized countries to account for the adjustment process towards the optimal capital stock. The idea is that fundamentals of the investment decision are aggregate demand and factor prices, whereas financial conditions have an incidence on the speed at which investment can be undertaken (for example, Gardner and Sheldon, 1975). Consequently, there should be a positive coefficient for

contemporary F_t values, but negative coefficients for lagged F_t values, and credit rationing would not modify the investment level in the long run. But this would not necessarily be the case in LDCs, if financial repression actually represented a long lasting obstacle for capital accumulation.

Foreign exchange shortage

Finally, the firm can be rationed by foreign exchange availability. Provided that a given share ϕ of total investment must be imported, such a rationing sets the upper limit for machinery and equipment purchases. Hence, equation (5) is binding, and gives rise to the following investment rule:

$$\frac{IP_t}{KP_t} = \phi_{x\varphi} \cdot \frac{x_t \cdot A_t}{v_t \cdot KP_t}, \quad \phi_{x\varphi} = 1/\phi \quad (12)$$

Once again, the main structural parameters of the model cannot be drawn from this equation.

4. MAIN EMPIRICAL FINDINGS

The discussion above shows that there are many competing specifications for the investment function depending on the values of some key parameters of the economy, and on whether or not some quantity constraints are binding. Now, the empirical performance of such equations must be considered.

From theory to estimation

Chart 1 summarizes the relationship between the theoretical models discussed above and the restrictions on the optimization problem of the representative firm. Each of the models is identified with a capital letter: from R for monopolistic competition without investment costs to X for foreign exchange shortage. These letters are the same as in the ϕ coefficients of the corresponding investment rules, represented by equations (6), (7), (8), (10), (11) and (12).

(Insert Chart 1)

The six theoretical models combine in different ways nine exogenous variables. Each of them is identified by a number, ranging from 1 (for the growth rate of demand) to 9 (for foreign exchange availability). Notice that these are the numbers associated with the ϕ coefficients in the six investment rules. For instance, the coefficient multiplying the growth rate of infrastructure is ϕ_{R2} in the monopolistic competition model, ϕ_{N2} in the neoclassical model and ϕ_{K2} in the Keynesian model.

The theoretical investment rules are not used in their pure form for the empirical task. A first set of adjustments concerns time lags.¹⁰ For instance, "time to build" has to be taken into account. Indeed, the theoretical models explain the decision to invest, whereas the data measure actual investment. The lag between both, which may be different from one investment project to another, arises because of delays required to choose, buy, receive and install new capital goods. Therefore, aggregate IP_t/KP_t should be related not only to the current values of the

10/ Although the model considered just two periods ("present" and "future"), one can proceed as if both of them included many years or quarters (say, t , $t-1$, $t-2$, ... and $t+1$, $t+2$, ... respectively).

exogenous variables but also to their lagged values. An additional "timing" problem with the investment rules discussed above concerns private expectations, which are not statistically observable. This is why variables such as Y_{t+1} , KG_{t+1} , w_{t+1}/P_{t+1} , etc. are replaced by distributed-lag functions relating their future level to their current and past values.

When time lags are considered, the six investment equations can be rewritten as in Chart 1.¹¹ In the latter, each of the ϕ coefficients is replaced by $\phi(L)$, with L being an operator such as $Lx_t = x_{t-1}$, and $\phi(L)$ representing a polynomial expression of degree k in L . It follows that $\phi(L).x_t$ is equal to $a_0.x_t + a_1.x_{t-1} + \dots + a_k.x_{t-k}$. The long-term coefficient of x_t , in turn, is the sum of the effects arising from x_t , x_{t-1} , ..., x_{t-k} , that is: $a_0 + a_1 + \dots + a_k$ or, in a more compact notation, $\phi(1)$. Such a long-term coefficient should be equal to the ϕ coefficient of the theoretical model. This is stated in the last column of Chart 1.

A second type of adjustment arises from aggregation. Each of the six investment equations is derived from the optimization problem of a single firm. However, it is intuitively clear that they can be combined in order to get mixed investment equations at the macroeconomic level. For instance, it could be assumed that a fraction μ of the firms does not face quantity rationing, either in the financial market or in the foreign exchange market. The investment rate u_t of these firms would therefore result from the theoretical models R , N , K or T depending on the values of parameters Γ and σ (say $u_t = u_{it}$ with $i = R, N, K$ or T). It could also be assumed that for a fraction Ω of the firms, the investment rate is bounded by credit availability ($u_t = u_{ft}$). Finally, in the remaining firms, the foreign exchange shortage

11/ For simplicity, in Chart 1 the number of firms (J) is treated as given.

would be the binding constraint ($u_t = u_{xt}$). Hence, the macroeconomic investment equation would be:

$$u_t = \mu \cdot u_{it} + \Omega \cdot u_{ft} + (1-\mu-\Omega) \cdot u_{xt} \quad (13)$$

with the analytical expressions of u_{it} , u_{ft} and u_{xt} given by Chart 1, and with μ and Ω set equal to either 0 or 1 based on prior information.

The coefficients in equation (13) can be written as $\mu \cdot \phi_i$ (with $i = R, N, K$ or T), $\Omega \cdot \phi_F$ and $(1-\mu-\Omega) \cdot \phi_X$, with the same analytical expression for ϕ_i , ϕ_F and ϕ_X as in Chart 1. In models R, N and K, the structural parameters α , β , τ and σ could be drawn from the ϕ coefficients. This was also true for parameter Γ in both the T and F models, and for parameter Φ in the X model. But in equation (13), the number of structural parameters is higher than the number of coefficients. Therefore, this second type of adjustment to the theoretical rules implies a significant loss of information on the key features of the economy.

Finally, the third type of adjustment represents an ad-hoc attempt to take into account the economic instability characterizing most LDCs. Often, an additional variable is included in the chosen specification, in order to measure the variance of some relevant macroeconomic aggregate, such as total output, returns on financial assets, etc.. Since an increased economic instability should depress private investment, the expected sign of the ϕ coefficient associated with this tenth variable would be negative whatever the chosen specification.

An overview of applied research

Available empirical studies on private investment in LDCs are not very numerous. It must be granted that standard macroeconometric models have been estimated in many countries in order to produce short-run forecasts. But their investment equations are often specified in a rather ad-hoc way. This is why we have preferred to survey a set of twenty-five recent studies which do specifically deal with private investment determinants in LDCs.¹² Their results are presented in Chart 2, whose first column identifies the corresponding authors and dates. Of course, this set of studies is far from being exhaustive. But since it includes a large variety of specifications, countries and data sources, it should provide a rather accurate picture of the state of the arts.

(Insert Chart 2)

As regards the countries, they are indicated in the second column of the Chart.¹³ A look at the list suggests that the sample has some regional bias: the share of Latin American countries seems excessively high, whereas just a few African countries are considered. Such a bias could arise from data availability. The latter could also account for the fact that only two estimates are based on microeconomic information (see column three). Nevertheless, the disaggregation level of the remaining studies is sometimes significant. For instance, one of them uses three-digit level information, whereas two others

12/ An additional study by Lim (1987) is set aside, because it is only incidentally concerned with investment, and the corresponding empirical equation does not lead to significant coefficients.

13/ The meaning of all the abbreviations used in Chart 2 (for countries, variables and econometric technique) can be found in the Appendix.

distinguish between small and large firms. Concerning the frequency of the series, only three of the studies stand on quarterly information, while the others are based on annual data.

The fifth column indicates the specification of the investment equation. Although the theoretical grounds provided by the authors may be different from those presented in section 3, in order to compare the results Chart 2 is only concerned with the exogenous variables considered in each case (1 to 9 in terms of the ϕ coefficients).¹⁴ Depending on the studies, these variables are sometimes lagged one period. More frequently, the investment equation includes a partial adjustment process (this is done in eleven cases).

In seven of the studies, the chosen specification corresponds to a "pure" model (R, N, K, T, F or X in terms of Chart 1), the "pure" effective demand specification being the only one which is not represented in the sample. In the remaining cases, instead of a single model, linear combinations of two or more specifications are used, as in equation (13). Most of them include an exogenous variable for credit, thus showing the wide acceptance of the F model for LDCs.

The fit of the estimated equations, measured by the adjusted coefficient of determination, can be found in the last column of Chart 2. Whereas the average coefficient is quite low (less than 0,7), there are large differences between studies, ranging from 0,08 to 0,99. However, one should be careful when assessing these results. On the one hand, low coefficients are quite common when using panel data, and such is the case for the lowest reported value. On the other hand, some of the best fits correspond to estimates in which the endogenous variable (fourth

14/ For instance, a specification including the income accelerator and relative factor prices is seen as arising from model R, unless it takes into account the rental-wage ratio (model K) or it omits aggregate demand (model N).

column) is not scaled, so that a high coefficient of determination could just reflect a spurious correlation between variables trending upward over time.¹⁵ The problem gets worse when a partial adjustment process is used, since the statistical adjustment may reflect serial correlation.

Estimated coefficients

Columns six to thirteen in Chart 2 embody the exogenous variables which may have an incidence on private investment decisions in LDCs. The estimated sign of the corresponding ϕ coefficients in each of the studies is indicated by "+" or "-" when they are not statistically significant, and by "++" or "--" when they are significant at the 5% level.¹⁶ Since eighteen of the studies are based on mixed investment rules (like equation (13)), there is almost no information on the structural parameters of the model. An attempt was made to draw their values from the ϕ coefficients of the remaining seven studies, but the results were rather discouraging, so that they will not be discussed. Instead, some regularities in the sign and significance of the estimated coefficients are noteworthy.

Aggregate demand appears as an important variable in the explanation of private investment levels. Included in all but eight of the studies, its coefficient is always positive and almost always statistically significant. This suggests that the pure neoclassical model (in which there is no income accelerator)

15/ Notice that in some cases, the endogenous variable is the whole investment, thus including government capital accumulation. Studies dealing with public sector investment only (such as those by Heller, 1975, and Chow, 1985) were set aside.

16/ In Chart 2, exogenous variables are multiplied by -1 whenever necessary to obtain coefficients whose expected signs are the same as in Chart 1.

may not be appropriate for LDCs. However, one should be careful concerning these results, because of the spurious correlation problem which was mentioned above: if investment is not scaled (by the capital stock, for instance) aggregate output could just be acting as a time trend.

Concerning public investment, although most of the studies discuss its crowding-out effects, only five of them account for the possibility of an externality on private investment.¹⁷ The corresponding coefficient has the "right" sign in two cases, thus reflecting a positive value of parameter τ . In a third study (by Gupta, 1984), the coefficient is negative despite the fact that the model is not based on the K specification (it does not consider the rental-wage ratio as an argument). The opposite is true for the study by Sundararajan and Thakur (1980), in which the empirical investment equation includes model K, but leads to a positive coefficient for public investment. In both cases, this would mean that infrastructure development gives rise to a negative externality ($\tau < 0$), which is rather surprising.¹⁸ In fact, the results could reflect a wrong appraisal of the goods market structure.

As regards relative factor prices, Chart 2 depicts a more disappointing panorama. Very often, they are not even taken into account in the empirical investment equations. Besides, in most cases they are not measured as required. This is what happens, particularly, with the user cost of capital, which is defined in the proper way only in four cases. In the remaining studies, it is replaced by a large variety of proxies, such as the ex-post

17/ We do not include among these the study by Tun Wai and Wong (1982), because government capital accumulation replaces aggregate output, so that it probably captures an income accelerator effect.

18/ We are not speaking about crowding out, since the empirical investment equations used by both Gupta and Sundararajan and Thakur take financial repression into account, by including savings availability among their arguments.

real interest rate, the actual or expected inflation rate, the relative price of capital goods, the assets-to-liabilities ratio, etc.. It must be granted that the corresponding coefficients have generally the right sign, but usually they are not statistically significant.

A theoretical reason that could account for this result is related to the structure of the goods market. Assume that the variety of available goods is low in LDCs, so that goods are weak substitutes. In terms of the demand curve faced by individual firms (equation (3)), the price-elasticity σ should be lower (in absolute values) than in industrialized countries. Now, coefficients ϕ_{K3} and ϕ_{K4} , which measure the elasticity of the optimal capital stock with respect to the user cost of capital and the real wage, are lower (in absolute values) the lower σ . Therefore, the higher monopoly power enjoyed by firms in LDCs could account for the "structuralist" flavour of the empirical results reported in Chart 2.

Four studies avoid taking factor prices explicitly into account by choosing the implicit approach, either in its pure form or combined with the F model. In all the cases, the coefficient of the q variable is positive and highly significant. Two of the studies also include a business-cycle indicator, which "corrects" the observable average q and leads to the (relevant) marginal q . The corresponding coefficients are positive and statistically significant, thus pointing out that increasing returns to scale more than offset the effect of a downward-sloping demand curve. These results suggest that the implicit approach may be a useful device in LDCs, in spite of the weakness of their capital markets.

Credit availability also emerges from Chart 2 as one of the decisive arguments for private investment in many LDCs. Indeed, financial variables are included in eighteen of the studies, and the corresponding coefficients have almost always the right sign

and are generally significant. However, as was the case for relative factor prices, financial variables are sometimes measured in quite misleading ways. Particularly, instead of credit availability (which is related to savings, banking system regulations, etc.), most of the studies consider actual credit, which represents just the "short side" of the financial market. In this case, the estimated coefficients do not convey information on whether investment decisions are determined by actual credit, or the opposite. Therefore, one should be careful when assessing the financial repression hypothesis from the results reported in Chart 2.

Foreign exchange availability is taken into account in five of the studies, by means of a large variety of statistical indicators: exports, international reserves, the real exchange rate, etc.. The corresponding coefficients have always the right sign and are almost significantly positive. However, a rise in the chosen statistical indicators could be seen as evidence reflecting that domestic economic policies are sound and sustainable. Expected profitability should therefore increase, even though aggregate demand, current factor prices, etc. remained unchanged in the short run. If this were so, the chosen balance-of-payment variables could be accounting for the "investment climate", and not necessarily for quantity rationing.

Finally, six studies include additional indicators for economic instability. In some cases, these are dummy variables, reflecting economic policy changes or uncertainties. Other studies measure instability through the standard deviations of either relative prices, aggregate output, or stock market yields. In all the cases, the corresponding coefficients have the expected sign and are statistically significant.

5. DEALING WITH ECONOMIC INSTABILITY

The results reported in chart 2 provide some support to the theoretical arguments discussed in Sections 2 and 3, concerning the determinants of private investment in LDCs. The estimated coefficients, particularly, have often the right sign and are generally significant. But the fit of the equations is not fully satisfactory, despite the scaling and autocorrelation problems mentioned above. This could be due to the aggregation criteria used to get a single equation from a large number of investment rules. Indeed, aggregation raises specific problems in a context of economic instability like the one characterizing most LDCs.

The most general specification (equation (13)) was obtained by assuming that a share μ of the firms did not face quantity rationing, whereas for shares Ω and $1-\mu-\Omega$ investment was determined by credit and foreign exchange availability respectively. Parameters μ and Ω could be set equal to zero or one based on prior information, but they were constant for the whole studied period. However, it is intuitively clear that μ and Ω could rise or fall significantly if the economic policy were sharply modified. For example, monetary tightness should increase the share of firms which face credit rationing, while the adoption of exchange rate controls should increase the share of firms constrained by available foreign currency. In this section, a rigorous aggregation procedure is chosen to deal with these changes.

The theoretical analysis presented in section 3 holds at the level of any single firm j , with $j = 1, 2, \dots, J$. So, the firm's investment rate is $u_{j,t} = (u_i)_{j,t}$ with $i = R, N, K$ or T if no quantity constraint is binding. If, on the contrary, firm j is rationed in the credit market, its investment rate is $u_{j,t} =$

$(u_F)_{jt}$. Finally, $u_{jt} = (u_X)_{jt}$ if firm j faces a foreign exchange shortage.¹⁹ This can be written as:

$$u_{jt} = \text{Min} \{ (u_I)_{jt}, (u_F)_{jt}, (u_X)_{jt} \} \quad (14)$$

The investment rates $(u_I)_{jt}$, $(u_F)_{jt}$ and $(u_X)_{jt}$ will generally differ from one firm to another, depending on their capital stock, their access to financial resources and foreign currency, etc.. Such a heterogeneity is captured by the following multiplicative model:

$$(u_I)_{jt} = u_{It} \cdot s_{Ij}, \quad (u_F)_{jt} = u_{Ft} \cdot s_{Fj}, \quad (u_X)_{jt} = u_{Xt} \cdot s_{Xj} \quad (15)$$

In equation (15), u_{It} , u_{Ft} and u_{Xt} are aggregate investment functions like those considered in Chart 1. Hence, they only depend on macroeconomic variables, like aggregate demand, average factor prices, etc. (this is why the "j" index is set aside). Concerning s_{Ij} , s_{Fj} and s_{Xj} , they represent positive disturbances which differ from one firm to another, but do not change over time (therefore, the "t" index can be omitted). Depending on their specific disturbances, some firms will be able to attain their desired investment rates, whereas others will be constrained either by credit or by foreign exchange.

Assume that s_I , s_F and s_X can be treated as independent stochastic variables, and let $h_I(s)$, $h_F(s)$ and $h_X(s)$ be their corresponding density functions. In this case, the aggregate investment rate is given by the following mean of equations (14):

19/ Models F and X do not entail restrictions on the structural parameters of the model (see Chart 1). Therefore, they are both compatible with any of the four other specifications (R, N, K or T).

$$u_t = \int_0^{+\infty} \int_0^{+\infty} \int_0^{+\infty} \text{Min}(u_{1t}s_{1j}, u_{ft}s_{fj}, u_{xt}s_{xj}) \cdot h_1(s_1)h_f(s_f)h_x(s_x)ds_1ds_fds_x$$

If, in addition, $h_1(s)$, $h_f(s)$ and $h_x(s)$ can be approximated by the same Weibull law with unit mean, it can be shown that the equation above becomes:

$$u_t = [u_{1t}^{-\pi} + u_{ft}^{-\pi} + u_{xt}^{-\pi}]^{-1/\pi} \quad (16)$$

(see Gouriéroux, Laffont and Monfort, 1984, p.28).

In equation (16), the π parameter ($\pi > 0$) arises from the Weibull law, and is higher the lower the variance of disturbances s_1 , s_f and s_x . Notice that for $\pi \rightarrow +\infty$, the right-hand side of equation (16) becomes a minimum condition. In economic terms, the variance of the s_1 , s_f and s_x disturbances is zero, so that for given levels of u_{1t} , u_{ft} and u_{xt} , all the firms are in the same situation. Consequently, there are no aggregation problems, and the investment rate for the whole economy is just the lowest of three different rates arising from competing specifications, which can all three be expressed in the same way as for a single representative firm.²⁰

Equation (16) is close to the investment rule developed by Lambert (1986). In his model, the optimal capital stock could be explained by two competing specifications, while an error correction mechanism led to the investment equation to be estimated. However, the Lambert model was only concerned with shortages in the goods market (in terms of section 3, the competing specifications would be models K and N). Equation

20/ This leads to a specific econometric problem, since there is no information on whether an observation u_t arises from the u_{1t} model, from the u_{ft} model or from the u_{xt} model. Quandt (1988) provides useful tools to deal with such a problem.

(16), on the contrary, allows for a wider range of constraints on the firms' optimization problem.

Equation (16) is also close to the kind of weighted average represented by equation (13), on which stood most of the applied research discussed in section 4. However, there are two important differences between these two specifications. First of all, in equation (16) parameter π is estimated simultaneously with the ϕ coefficients in u_{1t} , u_{Ft} and u_{xt} . Since the values of the structural parameters of the model are to be drawn from these coefficients, equation (16) avoids the loss of information which characterized equation (13).

The second difference concerns the μ share of non-constrained firms and the Ω share of firms facing quantity rationing. In equation (13) these shares were constant. In equation (16), on the contrary, they both change over time, their optimal estimates for period t being:

$$\mu_t = \left[\frac{u_{1t} - \pi}{u_t^*} \right], \quad \Omega_t = \left[\frac{u_{Ft} - \pi}{u_t^*} \right] \quad (17)$$

with u_t^* representing the forecast of the aggregate investment rate (see Sneessens and Dréze, 1986). Once the parameter π and the ϕ coefficients in u_{1t} , u_{Ft} and u_{xt} have been estimated, these shares can be easily calculated. Therefore, equation (16) allows a more accurate analysis of private investment determinants. For example, there could be a depressed investment rate in some periods because of generalized credit rationing (i.e. because of a low u_{Ft}), while in some other periods the same outcome could arise from low profitability (low u_{1t}). Such shifts are not observable when using equation (13) for empirical research.

As a result, equation (16) allows to analyze the changing effects of economic policy measures depending on the current

situation. For instance, when an important share of the firms face credit rationing (Ω_c large), a higher public investment could lead to a significant crowding-out of private investment. On the contrary, when private investment is low because of a depressed profitability (μ_c large), the development of the country's infrastructure would have a positive impact, because it imposes an externality on private profits.

6. CONCLUDING REMARKS

The determinants of private investment decisions in LDCs are not necessarily the same as in industrialized countries. The discussion above points out that there are specific issues, arising from a different macroeconomic and institutional setting, such as financial repression, foreign exchange shortage, lack of infrastructure and a significant economic instability. The available empirical studies, in turn, provide some support to these arguments. Hence, their careful introduction into the theoretical models from which investment equations are drawn would deserve further research. This is the case, particularly, with the intertemporal dimension of the analysis, restrained in this paper to a simple two-period framework.

With a few exceptions, the available empirical studies cannot be considered fully satisfactory. The endogenous variable is seldom scaled, as would require the theoretical models, so that it probably gathers a time trend. Moreover, some key exogenous variables, such as the user cost of capital, are measured in misleading ways. This is also the case with the upper bounds on credit and foreign exchange availability, which define two quantity constraints particularly relevant in LDCs. This measurement issue would also deserve further research.

Finally, the paper stresses the importance of the aggregation procedure in the context of a significant economic instability. Sudden and dramatic policy changes put forward the Lucas critique, since they modify the relevant investment rule. By raising or decreasing the share of firms which face credit or foreign exchange rationing, these changes avoid using a representative firm approach. The paper includes a methodological proposal to deal with this problem. Applied research would help deciding whether or not the suggested procedure improves the econometric performance of empirical investment equations in LDCs.

Appendix

LIST OF ABBREVIATIONS

Variables

IP	Gross private investment (in real terms)
IG	Gross investment of the public sector (in real terms)
Y	Real aggregate output
YP	Private sector's real output
Y*	Potential output or time trend of actual output
y	Discounted average productivity of capital (in value terms)
KP	Private capital stock
KG	Public sector's capital stock
F	Financial resources available for the private sector (in real terms)
A	Foreign currency available for the private sector
P	General price index
P*	Expected price index
w	Nominal wages
v	Nominal market price of capital goods
r	Discount rate (or nominal interest rate)
x	Nominal exchange rate
c	Nominal user cost of capital
q	Ratio between the shadow price of capital and its replacement cost

Estimates

VAR.:	Exogenous variable
COEF.: + (or -)	Positive (or negative) coefficient. Not significant at the 5% level.
COEF.: ++ (or --)	Positive (or negative) coefficient. Significant at the 5% level.

Econometric technique

OLS	Ordinary least squares
2SLS	Two-stage least squares
3SLS	Three-stage least squares
ML	Maximum likelihood
FIML	Full-information maximum likelihood
AR	Autoregressive
IV	Instrumental variables

Countries

		Kor	Republic of Korea
Arg	Argentina	Mal	Malaysia
Bar	Barbados	Mex	Mexico
Bol	Bolivia	Mor	Morocco
Bra	Brazil	Nic	Nicaragua
Chi	Chile	Pak	Pakistan
Col	Colombia	Pan	Panama
Cos	Costa Rica	Par	Paraguay
Dom	Dominican Republic	Per	Peru
Ecu	Ecuador	Phi	Philippines
Eth	Ethiopia	Sal	El Salvador
Gha	Ghana	Sin	Singapore
Gre	Greece	Sri	Sri Lanka
Gua	Guatemala	Tai	Taiwan
Guy	Guyana	T&T	Trinidad and Tobago
Hai	Haiti	Tha	Thailand
Hon	Honduras	Tur	Turkey
Ind	India	Uru	Uruguay
Ins	Indonesia	Ven	Venezuela
Jam	Jamaica	Zim	Zimbabwe

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Model	Restrictions on the parameters	Quantity constraints		Empirical investment equation	Long-run coefficients
		Credit	Foreign exchg.		
R	$\Gamma = 0$ $\sigma > 1$ $\alpha + \beta < \frac{\sigma}{\sigma - 1}$	No	No	$\frac{IP}{KP} = \delta + \phi_{R1} \hat{(L).Y} + \phi_{R2} \hat{(L).KG} + \phi_{R3} \hat{(L).(-)}^C_P + \phi_{R4} \hat{(L).(-)}^W_P$	$\phi_{R1}(1) = \frac{1}{(\alpha + \beta) + (1 - \alpha - \beta)\sigma}$ $\phi_{R2}(1) = \frac{\gamma(\sigma - 1)}{(\alpha + \beta) + (1 - \alpha - \beta)\sigma}$ $\phi_{R3}(1) = \frac{-\beta(1 - \beta)\sigma}{(\alpha + \beta) + (1 - \alpha - \beta)\sigma}$ $\phi_{R4}(1) = \frac{\beta\beta\sigma}{(\alpha + \beta) + (1 - \alpha - \beta)\sigma}$
N	$\Gamma = 0$ $\sigma \rightarrow +\infty$ $\alpha + \beta < 1$	No	No	$\frac{IP}{KP} = \delta + \phi_{N2} \hat{(L).KG} + \phi_{N3} \hat{(L).(-)}^C_P + \phi_{N4} \hat{(L).(-)}^W_P$	$\phi_{N2}(1) = \frac{1}{1 - \alpha - \beta}$ $\phi_{N3}(1) = -\frac{1 - \beta}{1 - \alpha - \beta}$ $\phi_{N4}(1) = -\frac{\beta}{1 - \alpha - \beta}$
K	$\Gamma = 0$ $\sigma = 0$	No	No	$\frac{IP}{KP} = \delta + \phi_{K1} \hat{(L).Y} + \phi_{K2} \hat{(L).KG} + \phi_{K5} \hat{(L).(-)}^C_W$	$\phi_{K1}(1) = \frac{1}{\alpha + \beta}$ $\phi_{K2}(1) = -\frac{1}{\alpha + \beta}$ $\phi_{K5}(1) = -\frac{\beta}{\alpha + \beta}$
T	$\Gamma > 0$ $\sigma > 1$	No	No	$\frac{IP}{KP} = \phi_{T6} \hat{(L).(\sigma - 1)} + \phi_{T7} \hat{(L).y}$	$\phi_{T6}(1) = 1/\Gamma$ $\phi_{T7}(1) = -\frac{(\alpha + \beta) + (1 - \alpha - \beta)\sigma}{\Gamma(\sigma - 1)(1 + \delta)}$
F	No restrictions	Yes	No	$\frac{IP}{KP} = \frac{P.F}{v.KP} + \phi_{F8} \hat{(L).(\frac{P.F}{v.KP})}^2$	$\phi_{F8}(1) = -\Gamma$
X	No restrictions	No	Yes	$\frac{IP}{KP} = \phi_{X9} \hat{(L).(\frac{x.A}{v.KP})}$	$\phi_{X9}(1) = 1/\phi$

Study	Countries	Date	Endogenous variable	Theoretical model	Aggregate demand (1)	Public capital stock (2)	Relative factor prices (3),(4),(5)	Average Tobin's q (6)	Business-cycle indicators (7)	Credit availability (8)	Foreign exchange availability (9)	Economic instability (10)	Source, fit and technique
Behrman (1972)	Chi	Macro (6 sectors) Annual 1945-65	IP t	R One equation for each sector	VAR.: Y^p_t / Y^p_{t-1} (Omitted for manufacturing sector)	Omitted	$\frac{d(c/P)}{dt}$ VAR.: Y^p_t / Y^p_{t-1} COEF.: --					VAR.: Standard deviation of relative output price over three years COEF.: --	Reported coefficients are for the manufacturing sector (equation Man 3) $R = 0.59$ (ML + Hall & Sutch for lags)
Bilsborrow (1977)	Col	Macro (22 manuf. firms) Annual 1950-64	KP t	R, F, X Variables are means across the 22 firms	VAR.: Y^p_{t-1} COEF.: ++	Omitted	VAR.: Minus the assets-to-liabilities ratio in $t-1$. Estimates for individual firms only. COEF.: --			VAR.: $(PF/v.KP)_{t-1}$ With F = firms internal funds COEF.: ++	VAR.: A With A = international reserves in $t-1$ + exports in t COEF.: ++		From equation (7): time-series $R = 0.50$ (OLS)
Blejer & Khan (1984)	Arg Bra Chi Col Cos Dom Ecu Gua Hai Hon Ind Kor Mal Mex Pan Par T&T Tha Tur Sin Sri Ven	Macro Annual 1971-79	IP t	K, F With a lagged IP + a dummy for each country	VAR.: Y_{t-1} COEF.: ++	VAR.: IG t COEF.: --	Omitted			VAR.: dF/dt Change in actual credit + net capital inflows to private sector COEF.: ++		VAR.: $Y_t - Y_{t-1}$ (Intended to capture cyclical fluctuations) COEF.: --	From equation (21) $R = 0.93$ (OLS; grid search for AR parameter)
Daillami (1987a)	Bra	Macro Annual 1958-84	dIP dt t	R With a lagged endogenous variable	VAR.: dY/dt t COEF.: ++	Omitted	VAR.: $d(c/P)/dt$ t COEF.: -- VAR.: $d(w/P)/dt$ t COEF.: +					VAR.: Risk premium (stock market volatility) COEF.: --	From equat. (20) (unconstr. estimates, Table 2) $R = 0.39$ (ML; grid search for AR parameter)
Daillami (1987b)	Kor	Macro Annual 1963-83	IP t KP t	T, F				VAR.: \bar{q}_t t COEF.: ++	Omitted	VAR.: Estimated shadow price of additional credit COEF.: ++			From equation (15) R not reported (ML)
Daillami (1989)	Col	Macro Annual 1971-86	IP t	R, F	VAR.: Y_t t COEF.: ++	Omitted	Omitted			VAR.: F t With F = total loans from financial institutions COEF.: ++			From equation (4) in Table 2 $R = 0.44$ (OLS)

Study	Countries	Date	Endogenous variable	Theoretical model	Aggregate demand	Public capital stock	Relative factor prices	Average Tobin's Q	Business-cycle indicators	Credit availability	Foreign exchange availability	Economic instability	Source, fit and technique
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Deilami & Melton (1989)	Zim	Macro Annual 1970-87	IP t	R	VAR.: y_t COEF.: ++	Omitted	VAR.: v_t/P_t COEF.: - VAR.: $r_t - P_t$ COEF.: -					VAR.: spread between domestic and international interest rates COEF.: --	From equation (4) in Table 2.1 $R^2 = 0.68$ (OLS)
De Melo & Tybout (1986)	Uru	Macro Annual 1962-83	IP t y_t	R, F, X With a lagged endogenous variable	VAR.: y_t COEF.: + VAR.: y_{t-1} COEF.: ++	Omitted	VAR.: $r_t - P_t$ COEF.: -			VAR.: Real money growth COEF.: + (t) COEF.: ++ (t-1)	VAR.: Real exchange rate COEF.: +		Includes a significant dummy for financial liberalization. From Table 7, column 4. $R^2 = 0.82$ (IV)
Fry (1980)	61 LDCs	Macro Annual 1964-76	IP + IS t y_t	R, F, X A lagged endogenous variable + a dummy for each country	VAR.: y_t COEF.: ++	Omitted	VAR.: P_t/P_t COEF.: --			VAR.: F_t/Y_t COEF.: + VAR.: F_t/Y_t COEF.: ++ With F = domestic credit	VAR.: A_t/Y_t With A = foreign exchange receipts COEF.: ++ VAR.: Purchasing power of exports COEF.: ++		From equation (4) in Table 3. $R^2 = 0.68$ (2SLS)
Galbis (1979)	Arg Bol Bra Col Cos Dom Ecu Gua Hon Mex Nic Pan Par Per Sal Uru	Macro Annual 1961-73	IP t y_t	M One equation for each country		VAR.: IG y_t COEF.: +	VAR.: P_t COEF.: -						From equation (2). Reported coefficients are averages for the 16 countries. $R^2 = 0.23$ (OLS)
Garcia (1987)	Bra Uru Ven	Macro Annual 1970-85	IP t	R, F One equation for each country	VAR.: y_t/Y_t COEF.: ++	Omitted	Omitted			VAR.: F_t With F = real non-wage income COEF.: ++			From equation (7) (reported coefficients correspond to Brazil). $R^2 = 0.94$ (OLS)
Gupta (1984)	Arg Bol Col Cos Dom Ecu Gua Hon Ind Ins Kor Mal Mex Pak Pan Par Per Phi Sal Sin Sri Tai Tha Uru Ven	Macro Annual 1967-77	IP t	R, F Estimated for full sample and 3 country groups	VAR.: y_t COEF.: ++	VAR.: IG t COEF.: --	VAR.: r_t COEF.: -- VAR.: $r_t - P_t$ COEF.: --			VAR.: F_t With F = private savings in financial assets COEF.: ++			Coefficients correspond to 8 low inflation countries. R^2 not reported (2SLS)

Study	Countries	Data	Endogenous variable	Theoretical model	Aggregate demand (1)	Public capital stock (2)	Relative factor prices (3),(4),(5)	Average Tobin's q (6)	Business-cycle indicators (7)	Credit availability (8)	Foreign exchange availability (9)	Economic instability (10)	Source, fit and technique
Leff & Sato (1989)	Arg Bol Bra Chi Col Cos Dom Gua Guy Has Hon Jam Mex Nic Pan Par Per Sal T&T Uru Ven	Macro Annual 1955-83	$IP_t + IG_t$	R,F One equation for each country	$VAR.: dY/dt$ COEF.: **	Omitted	$VAR.: \frac{\dot{P}}{P} - \frac{\dot{q}}{q}$ COEF.: --			$VAR.: dF/dt$ With F = stock of real credit COEF.: **			From equation (5). Reported coefficients are averages for the 21 countries. $R^2 = 0.2$ R not reported (3SLS)
Love (1989)	Bra Col Cos Eth Gha Gua Hon Mex Nor Nic Pan Sal	Macro Annual 1960-84	$dIP_t + IG_t$ dt	T One equation for each country						$VAR.: Exports$ (deviations from time trend) COEF.: ** $VAR.: International reserves$ (dev. from trend) COEF.: *			From equation (1). Reported coefficients are averages for the 12 countries. $R^2 = 0.35$ (OLS)
Ocampo et al. (1988)	Col	Macro Annual 1950-80	$IP_t + IG_t$ t Machinery and equipment only	R,X	$VAR.: dY/dt$ COEF.: *	Omitted	$VAR.: v/P$ t t COEF.: --				$VAR.: A$ dummy accounts for years with import controls COEF.: --		From Table 8, 6th equation $R^2 = 0.77$ (OLS)
Pereira-Leite & Vaz-Zadeh (1986)	Kor	Macro (manufact. sector) Annual 1970-81	IP_t	R,F With a lagged KP	$VAR.: YP_t$ (manufacturing sector only) COEF.: **	Omitted	$VAR.: r - P$ t t COEF.: -			$VAR.: F_t$ With F = internal financing (small firms) or bonds & foreign finance (large firms) COEF.: **			Last equation for small firms $R^2 = 0.97$ Fourth equation for large firms $R^2 = 0.95$ (OLS)
Rama (1987)	Uru	Macro Quarterly 1976-85	IP_t (Machinery only)	T,F With variable weights (disequil. estimates)				$VAR.: \frac{\dot{q}}{q} \cdot \frac{v}{P}$ t t t COEF.: **	$VAR.: y_t$ With y = excess demand arising from a disequilibrium model COEF.: **	$VAR.: current profits$ (COEF.: **), accumulated liabilities, (COEF.: --), foreign savings (COEF.: +) and government savings (COEF.: --)			From equat. (21). Reported coefficients are averages on 3 and 11 quarters lags $R^2 = 0.84$ (ML)
Schwartzman (1984)	Per	Micro (23 manuf. firms) Annual 1966-82	IP_t KP	T				$VAR.: \frac{\dot{q}}{q}$ t COEF.: **	Omitted				From equat. (23) (estimates in Table VIII) $R^2 = 0.08$ (OLS)

Study	Countries	Date	Endogenous variable	Theoretical model	Aggregate demand (1)	Public capital stock (2)	Relative factor prices (3),(4),(5)	Average Tobin's q (6)	Business-cycle indicators (7)	Credit availability (8)	Foreign exchange availability (9)	Economic instability (10)	Source, fit and technique
Solimano (1980)	Chi	Macro Quarterly 1977-87	IP t	T, F With a lagged endogenous variable				$VAR: \bar{q} = v/P$ t t t COEF.: ++	$VAR: Y$ t COEF.: ++	$VAR: F$ t With F = stock of real credit COEF.: ++		$VAR: Y$ Variance of Y over 4 quarters COEF.: --	$R^2 = 0.79$ (2SLS) Stability examined by the Kalman-filter method
Sundararajan (1987)	Kor	Macro Annual 1963-81	IP t	K, F With a lagged KP	$VAR: YP$ t COEF.: ++	$VAR: KB$ t Not significant. COEF. not reported.	$VAR: c/w$ t t With c depending on the debt-to-equity ratio. COEF.: --			$VAR: P.F/v$ t t t With F = gross savings - public investment COEF.: ++		Two significant dummy variables account for economic policy changes and uncertainties	From equation (11) estimates in Table 3, equation (21) $R^2 = 0.99$ (2SLS)
Sundararajan & Thakur (1980)	Ind Kor	Macro Annual 1960-76	IP t	K, F With a lagged KP. One equation for each country.	$VAR: YP$ t COEF.: ++ $VAR: YP$ t-1 COEF.: ++	$VAR: KB$ t COEF.: +	$VAR: c/w$ t-1 t-1 COEF.: -- $VAR: c/w$ t-2 t-2 COEF.: --			$VAR: P.F/v$ t t t With F = gross savings - public investment COEF.: ++			From equation (20). Reported coefficients are for India. $R^2 = 0.95$ (OLS)
Tun Hui & Wong (1982)	Gre Kor Mal Mex Tha	Macro Annual 1960-76	IP t	K, F With a lagged KP. One equation for each country.	$VAR: YP$ t COEF.: ++	$VAR: IG$ t But IG replaces YP, so that the coefficient captures the income accelerator effect	Omitted			$VAR: F$ t With F = change in bank credit or net capital inflow to the private sector COEF.: +			From equation (3) (reported coefficients are averages for the five countries) $R^2 = 0.95$ (OLS)
Tybout (1983)	Col	Macro 25 3-digit industries (2 sizes) Annual 1973-76	$(IP)_{ij}$ t (KP) $_{ij}$ t-1 (class size is industry j)	K, F With a lagged endogenous variable	$d(YP)/dt$ $_{ij}$ $VAR: (KP)_{ij}$ t-1 COEF.: ++	Omitted	Omitted			$VAR: dF/dt$ (KP) $_{ij}$ t-1 For class i, j with F = non-distributed profits (lag distribut.) COEF.: +			From equation (17) R^2 not reported (FIML, because of simultaneous estimates for small and large firms)
Van Wijnbergen (1982)	Kor	Macro Quarterly 1966-79	IP t	N, F With a lagged endogenous variable		Omitted	$VAR: r - P$ t-1 t-1 COEF.: --			$VAR: (dF/dt)$ t-1 With F = real credit to the private sector COEF.: ++			From equation (10) $R^2 = 0.80$ (2SLS, with seasonal dummies)
Vogel & Buser (1976)	Arg Bol Bra Chi Col Cos Ecu Gua Hon Mex NIC Par Per Sal Uru Ven	Macro Annual 1950-71	IP + IG t Y t	F With a dummy intercept for each country.						For F = currency outside banks, or demand deposits, coefficients were not significant			From equation (12) $R^2 = 0.62$ (OLS)

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